

APPLICATION
FOR
UNITED STATES LETTERS PATENT
ENTITLED

DYNAMIC PERFORMANCE MEASURES

TO WHOM IT MAY CONCERN:

BE IT KNOWN THAT (1) MELANIE RUSSELL and (2) FAYYAZ HUSSEIN,
of (1) ADDRESS and (2) ADDRESS, invented certain new and useful
improvements entitled as set forth above of which the following
is a specification:

PATENT GROUP
FOLEY, HOAG & ELIOT LLP
ONE POST OFFICE SQUARE
BOSTON, MA 02109-2170
TEL: 617-832-1000
FAX: 617-832-7000

05045399-050101
FOLEY, HOAG & ELIOT LLP

2
3 DYNAMIC PERFORMANCE MEASURES

4
5 BACKGROUND OF THE INVENTION

6 (1) Field of the Invention

7 The present invention relates generally to process control
8 indicators and more particularly to real-time indicators for
9 improved performance process control.

10 (2) Description of the Prior Art

11 In a process plant, various processes are employed to
12 produce amounts of a desired product. Traditional methods to
13 measure general performance of manufacturing operations of a
14 certain product include counting the amount of product produced
15 over a certain period of time, and from that amount, calculating
16 a cost per unit product. The cost per unit product is typically
17 based on a standard cost function that is associated with the
18 operation, often developed at the beginning of a fiscal time
19 period, and utilized throughout that period. The cost per unit
20 product is also often reported to manufacturing management to
21 evaluate manufacturing performance, and often serves as a primary
22 measure of manufacturing performance.

23 One disadvantage of measuring manufacturing performance by
24 cost per unit product is the equal distribution and allocation of

1 plant costs to each product or product line in the determination
2 of cost per unit product. Most costs in a manufacturing plant
3 are not directly assignable to a product or product line, and
4 therefore costs must be allocated as a function of other factors
5 that usually have more to do with the perceived performance of
6 the manufacturing operation than the actually occurring
7 manufacturing practices.

8 A second disadvantage of measuring manufacturing performance
9 by cost per unit product is that a considerable percentage of the
10 costs in a manufacturing plant for calculating the cost per unit
11 product, are not within the scope of manufacturing's authority;
12 therefore, the performance measurement of cost per unit product
13 leads to a "volume base" manufacturing approach that may not
14 properly satisfy market and corporate requirements.

15 Another disadvantage is that the calculation to determine
16 cost per unit product is a function of the amount of each product
17 or product line produced, and this calculation is not sensitive
18 to problems incurred in the producing a specific product. For
19 example, if a bad batch of a given product is produced and
20 discarded, a standard allocation algorithm cannot assign the
21 costs associated with that batch to the specific product, and the
22 costs are allocated to all products.

23 Other approaches to measuring manufacturing performance
24 involve non-cost/non-financial measurements and include

1 measurements of quality, delivery integrity and customer
2 satisfaction. These approaches are generally directed to the
3 discrete manufacturing industry and involve collecting
4 information and displaying results in a traditional daily,
5 weekly, or monthly report format. Such approaches do not provide
6 timely measurements to allow operations personnel to improve the
7 process on which the measurements were made.

8 There is currently not any sufficient systems or methods for
9 generating timely measurements of manufacturing systems
10 operations in the cement industry.

11 What is needed are methods and systems that allow cement
12 industry manufacturing systems personnel to measure manufacturing
13 processes to improve plant operations performance.

14 SUMMARY OF THE INVENTION

15 The systems and methods disclosed herein provide a real-time
16 (dynamic), sensor-based performance control apparatus that can be
17 utilized in a cement production process. The control apparatus
18 can employ a multiplicity of sensors and a computer processor for
19 providing a real-time indication of operating performance from
20 sensor signals. Performance can be indicated in terms of quality
21 of generated products, cost of production, down-time, yield,
22 and/or production.
23

1 Sensors can provide signals indicative of current state of a
2 respective process. A digital processor assembly can be coupled
3 to the sensors to receive the sensor signals. A computer can
4 support the digital processor to determine, from the sensor
5 signals, a quantitative measurement of current performance of the
6 manufacturing operations based on current operation of at least
7 one process. For example, the computer can calculate production
8 cost as a function of sensed current amounts of resources used,
9 and calculate quantity of production as a function of sensed rate
10 of operation of certain processes.

11 The computer can further provide screen views displayed on a
12 video display coupled to the digital processor assembly. The
13 screen views can display indications of the determined
14 measurement of current performance of manufacturing operations
15 with respect to a predetermined target performance measurement.
16 Subsequent operator adjustment through the control apparatus that
17 is coupled to the process, in accordance with the indications in
18 the screen views, can cause states of the process to approach
19 operation that provides a predetermined target performance of the
20 manufacturing operations.

21 Along with screen view displays, the computer can provide
22 audible and/or visible alarms in accordance with determined
23 performance measurements. The alarms can be coupled to the
24 digital processor assembly. For example, the computer can

1 provide an alarm when certain criteria are satisfied by a process
2 and/or by determined performance. For example, the computer can
3 enable an alarm when a determined performance measurement based
4 on current cost of production exceeds a predefined threshold,
5 and/or when determined performance measurement based on quality
6 is outside a predefined range.

7 In accordance with the methods and systems herein related to
8 a cement processing operation, sensors can include temperature
9 sensors, weight sensors, pressure sensors, etc.

10 In one embodiment, the digital processor assembly can
11 include processor modules. Different sensors can be coupled to
12 the different processor modules. Processor modules can have an
13 object manager to transmit respective sensor signals to a
14 computer upon request by the computer. Sensor signals can be
15 formed of a named series of data points stored in a memory area,
16 and object managers can enable access of data points by name
17 instead of memory location.

18 The computer can be coupled to an external system for
19 receiving pertinent predefined measurements of target
20 performance. A control apparatus can be coupled to the digital
21 processor assembly. Additionally, a processor member supported
22 by the digital processor assembly can receive working data from
23 the computer and store the working data on a common time-line in
24 a global database for general access. The working data can

1 include determined performance measurements, predetermined target
2 measurements, indications of sensed states of process means,
3 operator adjustments, and predefined thresholds for alarms. In
4 one embodiment, the database can be a relational database
5 accessible globally at subsequent times as desired for different
6 applications.

7 In an embodiment wherein the methods and system disclosed
8 herein can be applied to generate an advanced control solution
9 for a cement production system, the systems and methods can be
10 applied to a wet cement manufacturing process. In another
11 embodiment, the systems and methods can be applied to a dry
12 cement manufacturing process. In a cement production system,
13 sensors can provide measurements that can be related to the
14 efficiency of a kiln and a finishing mill that can be integral to
15 cement production quantity, quality, and cost. The sensor
16 measurements can be related to kiln and finishing mill cost and
17 production to allow manufacturing, engineering, operations, or
18 other personnel to alter processes and adjust the kiln and
19 finishing mill cost and production measures accordingly.

20 In an embodiment, kiln production can be measured and
21 monitored as a function of feed to the kiln less dust loss. Kiln
22 cost can thereafter be computed as a function of kiln production.

23 Alternately, finish mill can measure throughput as a function of
24 the fresh feed produced in tons per hour. Finish mill production

1 costs can be computed as a function of the finish mill throughput
2 and energy costs.

3 Other objects and advantages of the invention will become
4 obvious hereinafter in the specification and drawings.

5 6 BRIEF DESCRIPTION OF THE DRAWINGS

7 A more complete understanding of the invention and many of
8 the attendant advantages thereto will be readily appreciated as
9 the same becomes better understood by reference to the following
10 detailed description when considered in conjunction with the
11 accompanying drawings, wherein like reference numerals refer to
12 like parts and wherein:

13 FIG. 1 is a description of a cement production process as is
14 commonly known in the art;

15 FIG. 2 is an illustration of Dynamic Performance Measures
16 (DPMs) for the cement production process of FIG. 1;

17 FIG. 3A, 3B, 3C, and 3D present other displays that can be
18 generated from the DPM data of FIG. 2; and,

19 FIG. 4 provides an illustrative system for one embodiment of
20 the invention that utilizes the I/A Series system.

21 22 DESCRIPTION OF ILLUSTRATED EMBODIMENTS

23 To provide an overall understanding of the invention,
24 certain illustrative embodiments will now be described; however,

1 it will be understood by one of ordinary skill in the art that
2 the methods and systems described herein can be adapted and
3 modified to provide methods and systems for other suitable
4 applications and that other additions and modifications can be
5 made to the invention without departing from the scope hereof.

6 FIG. 1 shows an illustrative block diagram of a cement
7 product process 10 for a dry production process. As FIG. 1
8 indicates, limestone from a quarry 12 can be presented to a
9 crushing area 14 where it can be reduced to gravel size pieces
10 for presentation to a grinding area 16. The grinding area 16
11 blends raw materials in the proper proportions and grinds them
12 into a powder than can otherwise be known as Raw Meal. In an
13 alternate embodiment not shown in FIG. 1 and known as a wet
14 production process, water can be added to the raw feed during the
15 grinding process 16 to create a mixture called slurry. For the
16 purposes of the discussion herein, the FIG. 1 system shall be
17 understood to represent the well-known wet and dry processes, and
18 in accordance therewith, Raw Meal shall be understood to include
19 slurry. Returning to process referenced by FIG. 1, the Raw Meal
20 is presented to the Clinker Production area 17 that can include a
21 four stage Preheater 18, a Precalciner 20, a Kiln 22, and a
22 Cooling Area 24, although those with ordinary skill in the art
23 will recognize that the illustrated Clinker Production area 17 is
24 provided for illustration and not limitation, and fewer, more,

1 and/or substitute components of a Clinker Production area 17 can
2 be provided without departing from the scope of the invention.
3 The illustrated Preheaters 18 are vertical cyclone chambers
4 through which the Raw Meal passes. The Precalciner 20 accepts
5 the Raw Meal from the last stage of the Preheaters 18, and
6 performs a partial calcination process by introducing fuel,
7 thereby removing carbon dioxide. In the illustrated system, the
8 fuel is coal, although those with ordinary skill in the art will
9 recognize that other fuels can be used for the calcination
10 process, and other systems may use Pre-heaters with other numbers
11 of stages. After the passing through the Precalciner 20, the
12 material previously known as Raw Meal and heretofore referred to
13 as "the material" moves into the kiln 22, wherein remaining
14 carbon dioxide is removed and the intense heat begins to trigger
15 chemical reactions that turn the material, now precalcined, into
16 clinker. In the illustrated kiln 22, the material temperature
17 can reach twenty-seven hundred degrees towards the discharge end
18 of the kiln 22, wherein the material begins to form nodules that
19 can otherwise be termed clinker. In the FIG. 1 system 10, the
20 clinker retreats to the cooling area 24 where fans force cool air
21 over the clinker. In the illustrated system, the heat recovered
22 from the cooled clinker can be partially returned to the kiln 22
23 as secondary air to assist the primary combustion.

1 In a finish mill 26, clinker from the cooling area 24, known
2 otherwise as fresh feed, can be mixed with gypsum, slag, rich
3 limestone, etc., before being fed into a grinding mill that
4 grinds the treated clinker into a very fine powder. A separator
5 28 can accept the fine powder from the finish mill 26 and
6 distinguish between material that does and does not meet fineness
7 requirements. Material meeting the fineness requirement can be
8 stored in cement storage silos 30 for shipping at a later time,
9 while material not satisfying the fineness requirement can be
10 returned to the finish mill 26 as "reject" and combined with
11 fresh feed from the cooling area.

12 From the process of FIG. 1, it can be shown that a critical
13 part of the cement production process includes the making of
14 clinker. For systems according to FIG. 1, a clinker factor can
15 be computed and verified to satisfy a clinker production
16 efficiency. For example, a clinker factor of fifty-six one-
17 hundredths can indicate that for every ton of material that
18 enters the kiln 22, fifty-six one-hundredths of a ton of clinker
19 is produced. Fuel rate and feed rate to the kiln can therefore
20 be determined to be important factors to clinker production.

21 For the system of FIG. 1 wherein maximization of clinker
22 production for minimal cost is desired, a dynamic performance
23 measure (DPM) can be defined to maximize throughput of the
24 clinker production area 17, increase clinker quality, measure

burning efficiency, and optimize refractory life. DPMs are metrics that model performance measures in process manufacturing operations, wherein the metrics are derived from process instrumentation. DPMs can thus be calculated from a production process using real-time, preferably object-based process data to display results in real-time to operations, engineering, maintenance, and/or appropriate manufacturing or other personnel, as decision support tools for real-time plant operations. In an embodiment, the DPMs can be presented graphically, and the DPM results can be historized into a real-time database management system for later use, aggrandizement, and integration with other computer information systems of the manufacturing plant.

DPMs for a particular plant operation can be a function of the manufacturing strategy for that operation. The DPMs for one process or group thereof in one plant may not be appropriate for the same process of a similar but different plant. For example, if a manufacturing or process plant is production limited, primary measures can include yield or some other production-based statistic; but, if a manufacturing or process plant is not production limited, primary measures can be more resource-based.

Developing DPMs therefore includes determining a manufacturing strategy, and translating that strategy to specific measurements that can assist in determining whether the strategy is

1 successful, and this success can be measured on a process-by-
2 process basis.

3 Once specific measures are determined, sensor information to
4 make the measures can be determined. In many manufacturing and
5 process plants, the sensors to make the measures are already
6 installed in the manufacturing or control process. In some
7 cases, new sensors can be installed to complete the collection of
8 sensor-based information to measure the manufacturing or process
9 operations.

10 The sensor measurements can be input to a computer or other
11 processing module. In an embodiment, the sensors can transmit a
12 digital or analog signal to the computer that is equipped with
13 appropriate input/output capability to receive the sensor-based
14 information. The computer can convert, as necessary, the
15 incoming sensor signals into digital values that can be formed
16 into an input block that includes a collection of records or
17 fields for sensor data. In an embodiment, a particular input
18 block corresponds to a particular sensor. An input block can
19 also provide general system access to the sensor data by name,
20 where the global name is based on the name assigned to the input
21 block. This data point or "object" value can be available to any
22 application on the computer, or to other computers in a network
23 to which the computer is connected, by specifying the name of any

1 input block or the name of the field or record of interest in the
2 input block.

3 Calculation algorithms can also be formulated as part of the
4 DPM construction. The calculation algorithms can mathematically
5 relate the sensor measurements to a measure of the manufacturing
6 strategy. The calculation algorithms can also include targeted
7 values, predetermined values, and comparisons between currently
8 calculated values and the target values.

9 In an embodiment, an object oriented programming based block
10 structure can be established for a computation algorithm. These
11 algorithm blocks can be preprogrammed for DPMs that are
12 frequently encountered, or they can be programmed for different
13 applications. The sensor-based data provides the input to the
14 algorithm blocks, and this can be accomplished by identifying in
15 the algorithm block, an input block name and an input block
16 parameter (field or record) of interest. The sensor data can
17 therefore be input to the algorithm block and manipulated
18 according to the mathematical relationships in the algorithm
19 block.

20 The algorithm block output can be a global object that can
21 be accessed by the computer or another computer in a network, for
22 example, by specifying the name of the producing algorithm block.

23 The output object values can be a basis for the DPMs of
24 interest.

1 In an embodiment, in an algorithm block, the current overall
2 performance of a manufacturing or plant operation can be computed
3 as a function of the sensor measurements. The calculated
4 performance can be compared to a targeted performance measure as
5 stored in, for example, an algorithm block or in a historian
6 database. The comparison results can be presented to a display
7 object and/or a historial database.

8 Display objects and display templates can be constructed for
9 standard presentations of the DPMs, and can include line graphs
10 that depict the DPM value over a period of time (historized), an
11 indication of the DPM target value, an indication of any
12 pertinent alarm limits. In an embodiment, the x and y axes can
13 be labeled for the application and include a directional
14 indicator showing the direction of increasing performance.
15 Display objects can be combined with other graphics to build an
16 entire display template.

17 Subsequent to the building and displaying of the comparison
18 results in various display objects, an operator/user can adjust
19 controls and hence processes accordingly. The real-time display
20 of the compared calculated performance and target performance in
21 terms of production/resource factors of administration, enables
22 operator adjustment of processes, and hence resource/production
23 factors, immediately during subject manufacturing toward target
24 performance, i.e., toward desired values of resource/production

1 factors. These adjustments can be recorded in a historian
2 database. A historian database can therefore include sensed
3 states of processes, operator adjustments, calculated performance
4 measurements, and predefined target measures.

5 Returning now to the generalized cement processing system
6 shown in FIG. 1, wherein manufacturing strategies include the
7 maximization of clinker production while minimizing cost, DPM
8 calculation algorithms can be defined as follows:

9

$$\begin{aligned} 10 \quad & \text{Clinker Production} = (\text{feed to kiln} - \text{dust loss}) * .56 \\ 11 \quad & \text{tons/hour} \end{aligned} \quad (1)$$

12
13 The "feed to kiln" can be either slurry or raw meal, depending
14 upon the wet or dry process, respectively. The computation for
15 clinker production of Equation (1) can also be interpreted and
16 expressed as a computation for kiln production. Alternately,
17 Clinker cost can be expressed as:

18

$$\begin{aligned} 19 \quad & \text{Cost per ton of Clinker} = (\text{Fixed Cost} + \text{Energy Cost} + \text{Fuel} \\ 20 \quad & \text{Cost} + \text{Raw Material Cost} + \text{Losses}) / (\text{Clinker Production}) \end{aligned} \quad (2)$$

21

22 If it is assumed that Fixed Cost and Raw Material Cost are
23 not variable and not subject to control by the operations or
24 other management personnel, etc., Equation (2) can be reduced and

1 expressed as a function of Equation (1) to represent the kiln
2 cost per ton of clinker, or more simply, cost per ton of clinker:

3
4
$$\text{Cost per ton of Clinker} = (\text{KWH} * \text{Cost of KWH}) + (\text{Coal feed}$$

5
$$\text{rate} * \text{Cost of coal}) + (\text{Other fuel feed rate} * \text{Cost of other}$$

6
$$\text{fuel})) / ((\text{feed to kiln} - \text{dust loss}) * .56 \text{ tons/hour}) \quad (3)$$

7

8 Those with ordinary skill in the art will recognize that
9 Equation (3) is computed with respect to tons, and therefore
10 items such as "coal feed rate" and "other fuel feed rate" should
11 be expressed in tons/hour. In Equation (3), other fuel feed rate
12 are variable and controllable, while the costs of the respective
13 quantities or measures (e.g., costs of KWH, coal, other fuel(s))
14 are not controllable and can be fixed or dictated by an outside
15 source or vendor.

16 In an embodiment, waste fuels can supplement coal feed,
17 wherein the cement manufacturer, etc., is paid to accept and
18 include the waste fuels with the coal feed at the input to the
19 kiln and/or precalciner. In an embodiment wherein waste fuels
20 are utilized, the cost of per ton of clinker as provided in
21 Equations (2) and (3) herein, can be modified by subtracting an
22 amount equal to the waste fuel credit in tons per hour.

23 For the illustrative system of FIG. 1, the kiln sensors can
24 provide measurements including kiln feed, temperature

1 measurements at the input and output of the preheater stages,
2 water content at the preheater stages, oxygen and carbon-
3 monoxide, cooling fan rotation and power (current, voltage,
4 etc.), coal feed and BTUs, secondary air temperature, cooler vent
5 temperature, clinker temperature in the cooling area, oil flow,
6 fan speed, damper, etc., and such measurements are provided for
7 illustration and not limitation. Those with ordinary skill in
8 the art will recognize that the invention herein is not limited
9 to the sensors, the sensor arrangement, or the format of the
10 sensor input or output. Any sensor or sensor measurement that
11 can be incorporated into a clinker production factor or a cost
12 per ton of clinker according to Equations (1) and (3) herein is
13 within the scope of the invention. Additionally, system
14 variables, including for example, stack particulates and residual
15 carbonate, although not measured directly, can be inferred using
16 a non-linear modeling technique based on neural networks.
17 Multivariable control can be implemented to control the process
18 (e.g., kiln) by comparing measured temperatures to theoretical or
19 ideal temperatures and automatically making the necessary
20 adjustments. For example, a multivariable control system such as
21 the Connaisseur System by Invensys Systems, Inc., can utilize
22 neural networks and/or fuzzy logic, although the invention herein
23 is not limited to such embodiments.

1 A second DPM can be provided for the Finish Mill 26 to
2 maximize throughput, minimize energy consumption, and minimize
3 recirculating load. For the Finish Mill 26, the following
4 computational algorithms can be developed:

5

$$\begin{aligned} \text{Finish Mill Throughput} &= \text{fresh feed to finish mill} \\ \text{(tons/hour)} & \end{aligned} \quad (4)$$

8

9 Referring to FIG. 1 with reference to Equation (4), the
10 fresh feed to the Finish Mill 26 is the amount of clinker input
11 to the finish mill. This fresh feed measurement does not include
12 reject as shown in FIG. 1, and although the FIG. 1 system
13 indicates that clinker from the kiln is input to the Finish Mill
14 26, it is not unusual for the fresh feed measurement to include
15 clinker from sources other than the kiln (i.e., cement processors
16 can purchase clinker from alternate sources).

17 Another algorithm relating to the Finish Mill 26 includes
18 the cost of cement:

19

$$\begin{aligned} \text{Cost per ton of cement} &= (\text{Fixed Cost} + \text{Energy Cost} + \text{Raw} \\ \text{Material Cost} + \text{Losses}) / (\text{Fresh Feed}) \end{aligned} \quad (5)$$

22

23 Once again, by eliminating the non-variable Fixed Cost and
24 Raw Material Cost from Equation (5), and incorporating Equation

1 (4) into Equation (5), the Cost per ton of cement ("Finish Mill
2 Cost") can also be expressed as:

3
4 Cost per ton of cement = ((KWH*Cost of KWH) + (Clinker Feed
5 Rate*Cost of Clinker) + (Gypsum Feed Rate*Cost of Gypsum)+
6 (Grinding Aide Feed Rate*Cost of Grinding Aide)/((Fresh Feed) -
7 Reject). (6)

8
9 Once again, in equations (5) and (6), quantities are
10 understood to be expressed in consistent units of tons/hour.
11 Fixed Cost and Raw Material Cost are not subject to control,
12 while Energy Cost (i.e., Clinker feed rate) and Losses (i.e.,
13 Grinding Aide feed rate) are variable and controllable by an
14 operator, management personnel, etc. Similarly, the Gypsum feed
15 rate is variable and controllable. Once again, costs of
16 respective elements (e.g., costs of KWH, Gypsum, Grinding Aide)
17 can be fixed by an outside source or vendor. The Cost of Clinker
18 can be determined from Equation (3), and can be variable
19 depending upon factors discussed previously in relation to
20 Equation (3). The Clinker Feed Rate as indicated by Equation (6)
21 represents the feed rate of Clinker to the Finish Mill 26 for the
22 representative system of FIG. 1.

23 For example, in the illustrated finish mill, measurements
24 can include feed at the input, reject at the input, energy, water

1 content, power, temperature, etc. Those with ordinary skill in
2 the art will recognize that the invention is not limited to these
3 parameters or the sensors for measuring the same, and the
4 invention includes any and all sensors and measurements that can
5 contribute to the determination of the factors of equations (4)
6 and (6) for the computation of the finish mill throughput and the
7 cost per ton of cement. Once again, depending upon the
8 computations of Equations (4) and (6), multivariable control can
9 be employed to perform automatic adjustment of sensors,
10 processes, etc., using mechanisms that can include neural
11 networks, fuzzy logic, etc.

12 In an embodiment, Operator displays for the two DPMs can be
13 provided on a single display, and can include metrics for clinker
14 (i.e., kiln) production, clinker (i.e., kiln) cost, finish mill
15 production, and finish mill cost. In another embodiment,
16 multiple displays can be used. As FIG. 2 indicates, the four
17 metrics can be provided as a function of time to an operator or
18 other user. An operator or other user viewing the DPMs can
19 determine instantaneously whether the production and/or cost
20 goals are being satisfied. As indicated earlier, alarms can be
21 used to alert the user to such conditions. Upon determining that
22 the production and/or cost goals are not being satisfied, the
23 user can determine whether one or more of the system variables
24 requires modification or adjustment. As also indicated earlier,

1 adjustments can be provided automatically using a multivariable
2 controller that can implement fuzzy logic, neural networks, or
3 other well-known techniques for classifying system conditions
4 and/or automating a controlled response.

5 In an embodiment, existing or new sensors measuring the KWH
6 of the kiln, the coal feed rate, fuel rate, feed, dust loss, and
7 the KWH of the finish mill, the clinker feed rate, gypsum feed
8 rate, grinding aide feed rate, fresh feed, and rejects, can
9 provide data that can be formed into input blocks, submitted
10 respectively to the computational algorithms as presented by
11 equations (3) and (6) to develop one or more display objects as
12 indicated in FIG. 2, for example. The presentation of such
13 information in real-time can allow an operator, user, etc., to
14 correlate a change in production or cost performance relative to
15 one of the parameters. An operator, engineer, etc., can view the
16 dashboard displays and make adjustments to the various parameters
17 to determine how the Clinker Production and Finish Mill
18 Production are affected as a function of cost. Those with
19 ordinary skill in the art will recognize that the sensor
20 measurements can be filtered and otherwise processed to eliminate
21 noise or other undesired signals or signal components.
22 Additionally, the processed or unprocessed sensor signals can be
23 provided as input to a neural network or fuzzy logic to detect,
24 for example, sensor failures and other conditions that can

1 warrant intervention of engineering or operations personnel.
2 Sensor failure conditions can also cause an alarm in an
3 embodiment.

4 FIG. 3A shows an alternate method for displaying the
5 information from the input blocks formed by the DPM process
6 described herein based on the FIG. 1 system. FIG. 3A presents a
7 daily display of Cement costs versus Clinker costs. FIG. 3B
8 provides an analysis of KWH for the Grinding Area, Raw Mill, and
9 Finish Mills. FIG. 3C illustrates Clinker Area Production versus
10 Cost for real-time and Year-to-date, while FIG. 3D presents the
11 difference, per day, in cost between a target cost and actual
12 costs. Those with ordinary skill in the art will recognize that
13 although the charts and figures of FIGs. 3A-3D were presented in
14 particular display formats, the invention herein is neither
15 limited to the information displayed, nor the format of the
16 displayed information.

17 Referring now to FIG. 4, there is shown an illustrative
18 system 40 that can be implemented in a cement production
19 manufacturing process such as the system of FIG. 1, can further
20 provide for implementation of DPMs as provided herein, and is
21 known as the I/A Series ® system from Invensys Systems, Inc. As
22 is well-known, the I/A Series ® system includes I/O Modules 42
23 such as the FBM44 modules, wherein the I/O Modules 42 can
24 interface to a Fieldbus 43 and hence to a Control Processor 44

1 such as the I/A Series ® CP40B. Data from sensors 46 can be
2 transferred to the I/O modules 42 using a transmitter, wherein
3 the I/O Modules 42 can convert the sensor data to a format
4 compatible with the Control Processor 44. In one embodiment of
5 the system, the Control Processor 44 can include at least one
6 processor that includes instructions for causing the processor to
7 implement control algorithms. The Control Processor 44 can
8 further include instructions for implementing DPMs such as those
9 provided herein by Equations (1) through (6). As shown for the
10 FIG. 4 system, the Control Processor 44 can interface to
11 Workstations 48 through an I/A Series Nodebus 50 that can be
12 compatible with Ethernet. The Workstations can be, for example,
13 the I/A Series system AW51E that or any other system that
14 provides the functionality described herein. The Workstations 48
15 can allow for the display of data such as that according to FIGs.
16 3A-3D herein to allow a processor engineer, manufacturing
17 personnel, etc., to monitor and/or affect the controlled systems.
18 The illustrated Workstations 48 can further interface to another
19 Ethernet 52 that provides an interface to, for example, a
20 corporate network that can be equipped with other Workstations
21 54, Personal Computers (PCs), etc., that can also have
22 instructions for causing the display of DPM and/or other
23 information to management or other entities. Historic

1 information can also be provided to such systems 54 for local
2 retrieval and analysis.

3 Returning to the Control Processor 44 of FIG. 4, depending
4 upon the control algorithms, DPM computations, and any
5 integration therein, the Control Processor 44 can be equipped to
6 transfer control data to, for example, the valves or sensors 46
7 via the I/O Modules 42 to achieve specified control objectives.
8 In one embodiment, the control objectives can be pre-programmed
9 using a multivariable control system such as the Foxboro
10 Connisseur system, however in other embodiments, manufacturing or
11 other process system adjustments can be made manually or through
12 the I/A Series Workstations 48.

13 One of several advantages of the present invention over the
14 prior art is that dynamic performance measures are generated to
15 relate sensor measurements in a cement processing system to
16 identifiable management goals of balancing cement production and
17 efficiency against production costs.

18 What has thus been described are methods and systems for
19 creating dynamic performance measures (DPMs) for a cement
20 production system. In an embodiment, clinker production and
21 finish mill production can be optimized by aggregating sensor
22 measurements from clinker production and finish mill production
23 processes, and determining measures in the form of DPMs related
24 to the productivity and cost of the clinker production and finish

1 mill production. The DPMs can be provided to a display that can
2 be viewed by manufacturing or other personnel. Control decisions
3 can be made to change the clinker production and/or finish mill
4 production processes while the results of such changes can be
5 reflected in real-time on the DPM displays.

6 Although the present invention has been described relative
7 to a specific embodiment thereof, it is not so limited.
8 Obviously many modifications and variations of the present
9 invention may become apparent in light of the above teachings.
10 For example, any sensors providing the necessary sensor
11 measurements can be used to construct the desired DPMs, and the
12 invention can utilize any sensors that provide measurements
13 according to equations (1), (3), (4), and (6). The block diagram
14 of the cement production process is merely illustrative and not
15 intended for limitation, and alternate cement production elements
16 can be included or otherwise eliminated without departing from
17 the scope of the invention. Although the equations were
18 presented for units of tons or tons/hour, other units of
19 measurement and/or time can be utilized to modify the equations
20 accordingly.

21 Many additional changes in the details, materials, steps and
22 arrangement of parts, herein described and illustrated to explain
23 the nature of the invention, may be made by those skilled in the
24 art within the principle and scope of the invention.

1 Accordingly, it will be understood that the invention is not to
2 be limited to the embodiments disclosed herein, may be practiced
3 otherwise than specifically described, and is to be understood
4 from the following claims, that are to be interpreted as broadly
5 as allowed under the law.

09846899.050101